Retention and Reacquisition of Military Skills

Dr. Mark A. Sabol

U.S. Army Research Institute
sabol@ari.army.mil

Dr. Robert A. Wisher

U.S. Army Research Institute
wisher@ari.army.mil

APPLICATION AREA:
Analytic Support to Training Retention and Reacquisition of Military Skills

OR METHODOLOGY:
Meta-analytic review

ABSTRACT

In the military, a primary assumption is that trainees will retain the knowledge and skills they acquire in training long enough to perform effectively on the job. However, decades of research have shown that significant forgetting can occur over even brief periods, depending on a host of factors. This paper examines our current understanding of skill decay, highlighting a series of studies that examined soldiers' skills during Operation Desert Storm and in subsequent mobilization exercises with the reserve component. Our concern is exclusively with individual, rather than collective, tasks. A proposal for predicting the time needed to reacquire lost skills is presented, along with supporting data.

INTRODUCTION

Every year the Army trains soldiers on over 40,000 tasks. Some tasks require only minutes of training, but the more complex tasks, such as repair of a radio communications system, may require several weeks of training per soldier. The Army assumes that the huge budget of time and money needed for this training is an investment that will pay off in later job performance. That is, soldiers will retain the knowledge and skills they acquire in training long enough to perform effectively in their career assignments.

However, people forget and skills get rusty. More than a century of research on memory (beginning with Ebbinghaus, 1885/1913), has shown that large amounts of forgetting can occur naturally over periods as short as several hours or as long as many years (Farr, 1987; Semb & Ellis, 1994; Arthur, Bennett, Stanush, & McNelly, 1998; Anderson, Fincham, & Douglass, 1999).

This report reviews what is known about forgetting as it applies to military tasks, concentrating on major projects conducted by the U.S. Army Research Institute (ARI) during the past three decades. Included are both basic research supported by ARI at universities (e.g., Healy, Ericsson, & Bourne, 1987; Jones, 1989; Healy & Bourne, 1995) and applied studies conducted in field settings by ARI researchers (e.g., Hagman & Rose, 1983) and by the Air Force and Navy. The Army research will focus on retention of skills by members of the Individual Ready Reserve (IRR). This review will make clear several ways the Army can minimize or reverse forgetting's effects.

Because forgetting may occur over any period when knowledge is not applied and skills are not practiced, Army planners and trainers need answers to the following questions:

1. How fast does forgetting occur for different kinds of skills?
2. Are some individuals more likely to forget than others?
3. What instructional strategies are effective in reducing forgetting?
4. How difficult will it be for soldiers to reacquire skills they have forgotten?

Answers to these questions are important for the development of effective initial and refresher training programs, mobilization policy, and reserve component training plans. This paper addresses each question in turn.

MEMORY FOR DIFFERENT KINDS OF SKILLS

As soldiers attempt to perform an already-trained military task, they rely on several different abilities: 1) ability to retrieve from memory previously-learned knowledge (job-related facts, rules, terminology, order of steps to be performed in a procedure, etc.); 2) ability to combine incoming information, evaluate a situation, and decide among alternative courses of action; and 3) ability to execute the chosen action or procedural step in a sufficiently skilled manner.

Consider a sports analogy: a quarterback whose coach has called in a pass play. The main task has been set, but three component tasks must be performed to successfully complete it. As the team huddles, the quarterback must recall what "45 Slot Hook Red" means in terms of the patterns the receivers will run. At the line of scrimmage, he must evaluate the set-up of the defense and, as the play unfolds, determine if the intended receiver is coming open. Once the decision to throw has been made, the quarterback must execute the pass precisely to get it within the receiver's reach. *Knowledge*, *decision*, and *execution*—these three components are present in most tasks, although tasks vary widely as to which component dominates.

In most military tasks, the first ability—*knowledge* retrieval—predominates. In one sense, this is true because soldiers must call to mind a number of job-related terms and rules as they carry out any task. But it is also true in the sense that there is a separate class of tasks that depend on information recall. These tasks are generally referred to as *procedural tasks*, because the crucial recall required is memory of the steps to be performed in a given procedure.

The second ability, *decision*—sometimes called cognitive processing—dominates in such tasks as trouble-shooting faulty equipment and selecting tactics to obtain an objective. These are often referred to as *cognitive tasks* (Allen, Secundo, Salas, & Morgan, 1983; Singley & Anderson, 1989).

In still other tasks, precise *execution* of well-practiced actions is the crucial aspect; such tasks are referred to in the psychological literature as psycho-motor or *perceptual-motor tasks* (Ammons, Farr, Bloch, Neumann, Day, Marion, & Ammons, 1958; Fleishman & Parker, 1962). The prime military example is target acquisition and tracking (Thompson, Morey, & Smith, 1981).

Much work in the neuroscience of human memory (see Gabrieli, 1998, for a review) indicates that these three types of abilities are located and controlled in different regions of the brain: verbal knowledge is encoded in the neocortex, usually in the left hemisphere; cognitive tasks are performed primarily in the frontal lobe; and skilled execution of perceptual-motor tasks is mediated by the cerebellum. As they are dependent on different areas of the brain, it is not surprising that the studies described below have shown a different pattern of forgetting for each type (Arthur et al., 1998; Farr, 1987).

Memory for Job Knowledge. All military tasks have a knowledge component, facts and ideas the soldier must remember in order to perform successfully. This information may be as basic as the definitions of task-relevant terms or as complex as the order in which the task's procedural steps should be performed. To disassemble the M240 coaxial machine-gun, for example, the soldier must remember not just the names, functions, and locations of the buffer assembly, bolt assembly, driving rod and spring, and trigger assembly, but also to remove the driving rod and spring before removing the bolt assembly.

An interesting early study of knowledge retention was conducted by the U.S. Army during the Second World War, as part of research designed to evaluate the success of a film series called "Why We Fight," shown to soldiers for the purpose of instilling confidence in the rightness of the Allies' cause (Hovland, Lumsdaine, & Sheffield, 1949). A fifty-minute film, "The Battle of Britain," was presented to 700 recruits during basic training. Either 5 days later (450 recruits) or 9 weeks later (250 recruits), a 10-item quiz was given, imbedded in a routine survey. The items on this quiz asked the recruits to select as true one of four statements based upon facts presented in the film. Examples of the true statements were: "Goering was the head of the German Air Force." "'Luftwaffe' was the name of the German Air Force." "The 'Luftwaffe' was ten times as large as the RAF."

The results showed substantial loss of factual information in the first months. While those who took the survey and quiz less than a week after seeing the film attained a score of 56% correct, those who took them only after another two months scored 41% correct. Control groups that did not see the film got 32% of the items correct. So more than half of the effect of viewing the film dissipated after 9 weeks.

When such factual information is not presented casually or incidentally but is stressed and studied, it is often referred to as school knowledge. Some studies of memory for knowledge learned in school have found remarkable resistance to forgetting for years after learning (Conway, Cohen, & Stanhope, 1991; Cohen, Stanhope, & Conway, 1992; Stanhope, Cohen, & Conway, 1993; Semb & Ellis, 1994). In fact, some kinds of school knowledge—for example, vocabulary from high school Spanish—appear to stay with a person for a lifetime (Bahrick, Bahrick, & Wittlinger, 1975; Bahrick, 1984; Bahrick & Hall, 1991).

However, a distinction based on the way performance is measured can be crucial; the amount of forgetting found depends on whether the test of memory required recognition or recall. *Recognition* memory involves choosing the correct response from a number of alternatives and is usually tested with multiple-choice, matching, or true-false items. *Recall* memory requires the learner to produce information without being presented with alternatives and is usually tested with short answer, fill-in, or essay test items. In general, because of the cues provided by the alternatives, recognition memory is superior to recall memory. Figure 1 summarizes the research findings from more than 40 studies (Semb & Ellis, 1994) of

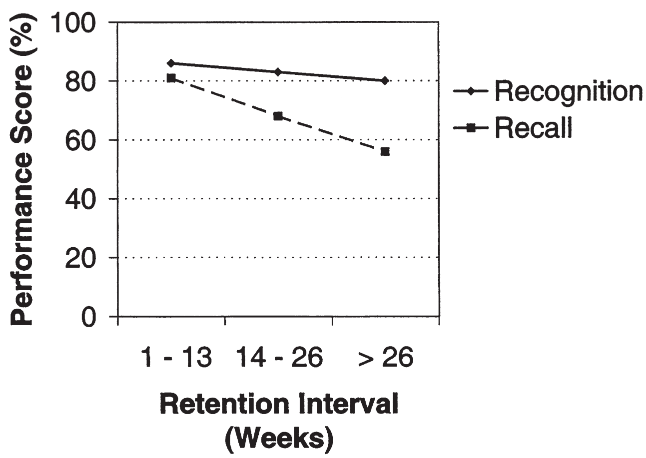

Figure 1. Average data from 40 studies of memory for school knowledge (from Semb & Ellis, 1994).

recognition and recall for retention periods up to 52 weeks.

Several military studies contributed to the results in Figure 1. For example, a study of recognition memory for propulsion engineering training at the Navy's training center at Great Lakes, Illinois, found that trainees remembered 91 percent after 4 weeks and 80 percent after 28 weeks (Ellis, 1980).

As mentioned above, procedural tasks constitute a special class among tasks that rely heavily on knowledge retrieval. Because procedural tasks require the soldier to produce a set of actions, they tend to suffer from the degradation over time seen in Figure 1 for performance measured by recall. An Air Force study, for example, looked at procedural skill loss among airmen while they were in the Individual Ready Reserve (IRR); among those separated from active duty for 18 to 24 months, only 53% retained proficiency (Davis, 1991).

Such procedural tasks are knowledge-dependent because they require retrieval of memory—both for the steps that must be performed and, in some cases, for the order in which they must be done. From another perspective, however, these tasks also form a bridge to the class of tasks, discussed below, for which well-practiced execution is key. But we turn first, briefly, to retention of cognitive or decision-making skills.

Memory for Decision Skills. Many military tasks involve cognitive components, such as problem solving, judgment, and analysis leading to a decision. For example, many troubleshooting tasks require soldiers to reason their way to the diagnosis of a particular fault in their equipment.

Research on memory for cognitive tasks shows a moderate rate of decay (Cooke, Durso, & Schvaneveldt, 1994); forgetting occurs but is relatively small for up to a year after learning. Figure 2 summarizes more than 20 studies (Semb & Ellis, 1994), including two studies of military tasks. One tested anti-submarine warfare trainees on the application of oceanography principles immediately and four weeks after training and found a 21% drop in scores (Wetzel, Konoske, & Montague, 1983). Another found a 16% loss of basic electricity problem solving skill after 8 weeks (Austin & Gilbert, 1973).

Memory for Execution Skills. Tasks in any Military Occupational Specialty (MOS) have an execution or performance component, although this aspect may be trivial when the performance involves behaviors practiced for years, or in some cases, over a lifetime. Administrative Specialists, for example, may complete many of their clerical tasks by simply filling out a form with a pencil or on a computer screen. Another MOS, however, may entail extensive skilled performance in using tools or operating complex equipment. For example, one of the task steps in boresighting the direct fire telescope on an M198 howitzer involves rotating the M32 periscope elevation and deflection boresight knobs until the aiming cross is on the upper left-hand corner of the target. This precise rotation requires considerable manual dexterity.

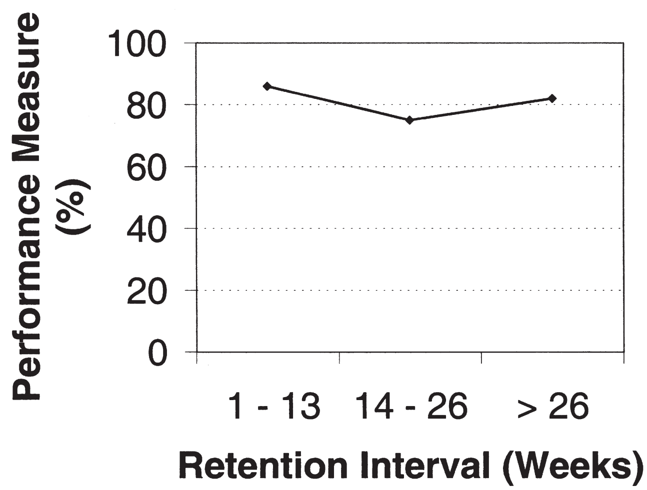

Figure 2. Average retention of 20 cognitive tasks (from Semb & Ellis, 1994).

Memory researchers classify such performance skills as either continuous or discrete (Schendel, Shields, & Katz, 1980). *Continuous* skills involve movements or steps that do not have distinct beginnings or endings; examples include driving a vehicle, keeping a weapon sight on a moving target, and flying an aircraft. As noted above, these are also called perceptual-motor tasks. *Discrete* skills, on the other hand, are needed for tasks with definite beginnings and ends—for example, starting up radio equipment, disassembling a carburetor, or performing a vehicle safety check. These can be recognized as what we earlier called procedural tasks. Research has shown that memory for continuous (perceptual-motor) skills is different from memory for discrete (procedural) skills.

As said above, skill at discrete, knowledge-dependent procedural tasks may show considerable decay in just a few weeks or months. In their review, Konoske and Ellis (1986) stated that "[p]rocedural tasks, the most important and necessary type of task for Navy mission readiness, consist of an ordered sequence of steps or operations performed on a single object or in a specific situation. They involve few decisions, are generally performed the same way every time, and are frequently not well retained" (page 1).

However, studies dating back to the 1950s (e.g., Lewis and Lowe, 1956; Roehrig, 1964) have found high long-term retention of skill at continuous tasks. Perceptual-motor tasks, such as typing, aircraft flight control, target tracking, marksmanship, or the proverbial bike-riding, show virtually no skill loss for periods as long as two years without practice (Adams, 1987; Hamilton, 1991; Wisher, 1991). In a study of helicopter pilots in the IRR (Cross & Szabo, 1986), for example, even airmen who had not flown for many years retained flying skills well and were able to reacquire any lost skill quickly.

Figure 3 shows data on memory for a typical example of one perceptual-motor task and one procedural task. These examples are taken from a study of skill retention conducted by ARI during the partial mobilization of the IRR during Operation Desert Storm (Wisher, Sabol, Sukenik, & Kern, 1991). In each case, a performance measure is shown as a function of "time out of service." That is, the three data points were obtained from groups of hundreds of ex-soldiers who had been called back to active duty and asked to perform tasks in their former military jobs after having been in civilian life differing lengths of time.

Memory for perceptual-motor skills, represented in Figure 3 by the marksmanship scores at TOW gunnery, shows much the same resistance to decay as was seen (Figure 2) in recognition memory for school knowledge; the mean gunnery score is above the "Go" level (600) at all retention intervals, even for soldiers out of active duty for a year. Discrete, procedural skill, however, may be forgotten much more rapidly; in Figure 3, scores on a test of memory for several quartermaster procedural tasks are

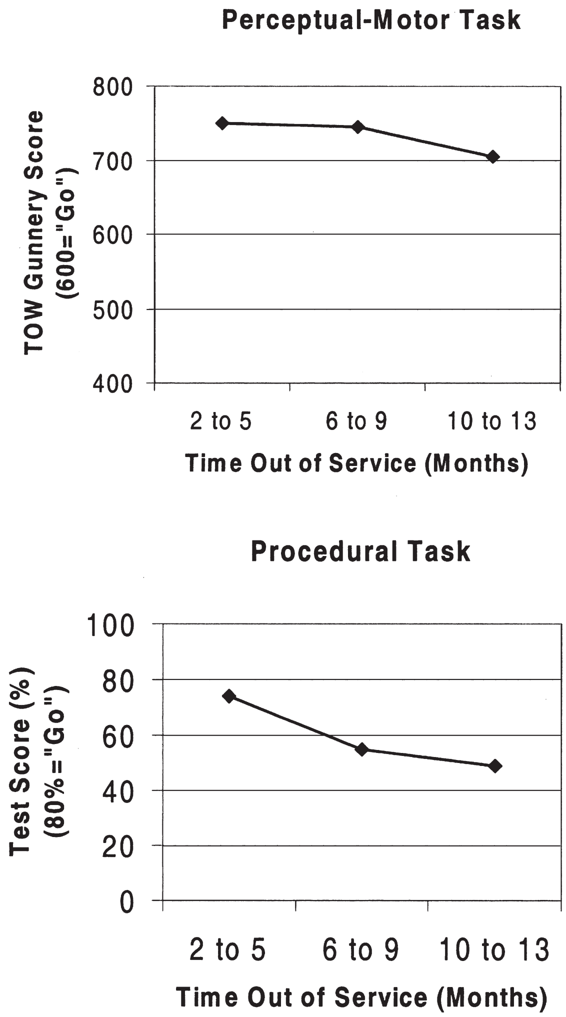

Figure 3. Typical memory for perceptual-motor (continuous) and procedural (discrete) tasks (from Wisher, Sabol, Sukenik, & Kern, 1991).

below the "Go" level (80%) for all retention periods.

Many procedural tasks show this quick decline. It has been found, for example, that only 20% of civilians trained on the first aid task of giving cardio-pulmonary resuscitation (CPR) are proficient six months later (Skelton & McSwain, 1977; McKenna & Glendon, 1985). There are also exceptions, however. A study of Army basic combat skills showed an average loss of as little as five percent after six weeks for some tasks (e.g., first aid for shock) and as great as 52 percent for others (e.g., clearing an M16 rifle) (Vineberg, 1975).

Figure 4 shows the theoretical set of curves that performance would be expected to follow (according to Rose, Czarnolewski, Gragg, Austin, & Ford, 1985). Each curve represents a different procedural task. Note that some of these tasks, those represented by the upper curves, suffer so little forgetting that they show fairly constant performance, month to month. Other tasks, those on the lower curves, show constant performance after the first few months, because most of the decay they will suffer has already occurred (Wick, Millard, & Cross, 1986). But there are many tasks in between these two extremes.

The variability of real-life results for discrete procedural skills is shown in Table 1. These data are from an ARI study of skill retention by 197 volunteers from the IRR (Wisher, Sabol, Maisano, Knott, Curnow, & Ellis, 1996). After being called back to active duty for a mobilization exercise, the soldiers were given hands-on tests of their memory for common soldiering tasks. All of these soldiers, who had been away from active duty for an average 36 months, performed all the tasks. The probability that a given soldier would perform at a "Go" level ranged across tasks from 73% to 17%.

This variability among discrete procedural tasks is important, because, as noted above, such procedural tasks constitute most of the tasks learned by soldiers and sailors. A similar wide range of retention was found for procedural tasks and instrument-flying skills needed by helicopter pilots, although their basic (perceptual-motor) flying skills were retained well (Prophet, 1976). Some way to account for this wide range of resistance to forgetting is needed. ARI's approach to this problem is described below.

FACTORS AFFECTING PROCEDURAL SKILL RETENTION

The inconsistency among individual studies of procedural skills occurs because a number of factors that affect forgetting vary from one study to the next. In the following sections, research is discussed in turn that identifies two classes of factors—task factors and individual soldier factors.

Task Factors. Forgetting of a procedural task is affected by three general factors that relate to the task itself: a. how complex the task is, b. how great the task demands are for knowledge, decision, and execution, c. how dis-

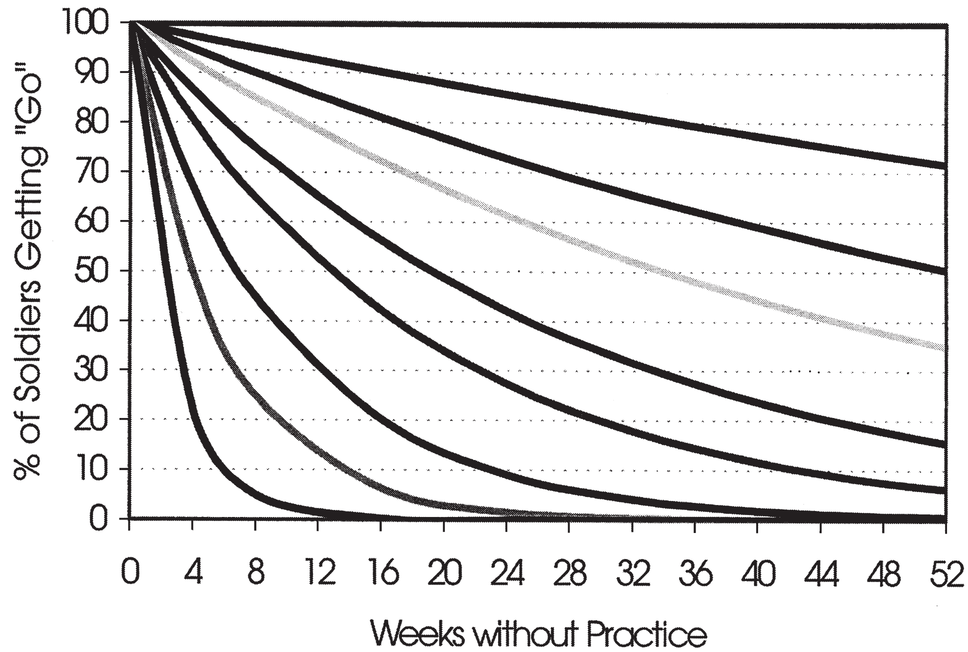

Figure 4. Theoretical set of curves for skill decay at different procedural tasks (drawn from equations given by Rose, Czarnolewski, et al., 1985).

Table 1. Mobilized IRR soldiers' performance on procedural common tasks before retraining

Tasks	*%GO*
Evaluate Casualty	73%
Prevent Shock	65
Apply Field Dressing	62
Wear M-17 Mask	37
Maintain M16A2 Rifle	35
Maintain M-17 Mask	34
Identify Terrain Features	28
Determine Ground Location	27
Perform Function Check M16	24
Correct Malfunction on M16	23
Determine Grid Coordinates	22
React to Chemical/Bio Hazard	19
Decontaminate Skin/Equipment	17

ruptive or helpful the environment is in which the task must be performed. After describing these factors below, we will describe the model that combines the factors to yield predictions of memorability for individual procedural tasks. The italicized statements are incorporated in this model.

a. Task Complexity. Three primary factors combine to determine a value we might call task "complexity." This overall measure turns out to be highly predictive of whether a task will be forgotten. A complex task is the opposite of one with an inherent organization that produces a "simplicity" or unity, where each task step follows logically or naturally from the one before. The component factors are: (1) how many *steps* there are in the task, (2) whether the steps must be performed in a set *sequence*, and (3) whether there is built-in *feedback* that indicates correct performance of task steps.

Several studies have shown that, *as the number of task steps increases, retention performance decreases* (Shields, Goldberg, & Dressel, 1979; Knerr, Harris, O'Brien, Sticha & Goldberg, 1984; Vineberg, 1975). The best example of this effect is an ARI study of more than 500 soldiers performing tasks learned in basic training. All soldiers, having demonstrated their ability to perform the tasks at the end of training, were then retested at periodic intervals. Figure 5 shows performance for four tasks 12 months after training. The tasks and number of steps are: (1) report enemy information, 3 steps; (2) load and fire M203 grenade launcher, 9 steps; (3) perform cardiopulmonary resuscitation, 14 steps; and (4) don gas mask, 15 steps (Shields et al., 1979).

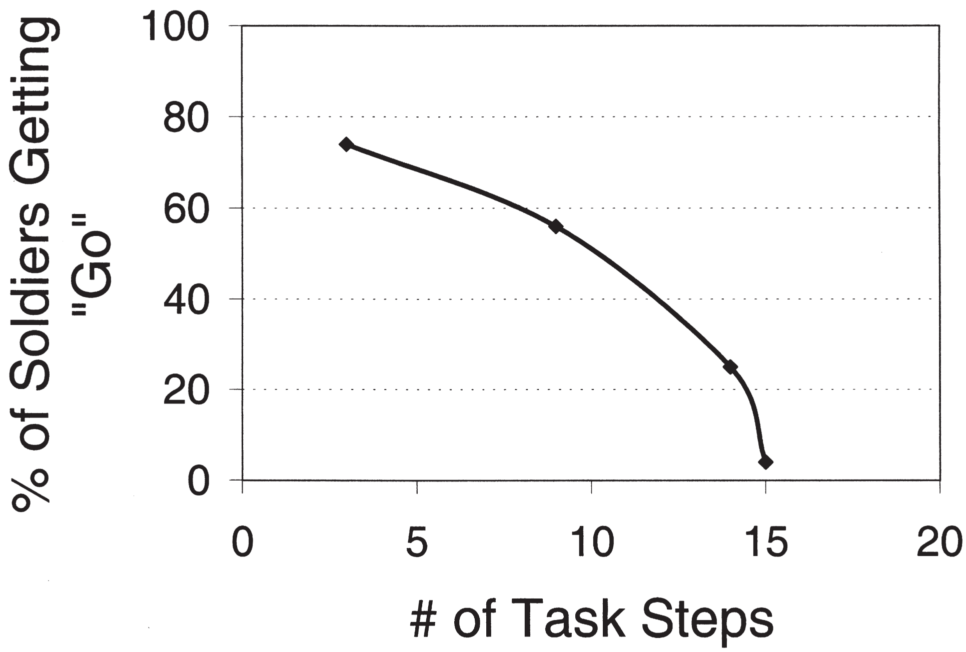

Figure 5. Task difficulty affected by adding task steps (from Shields et al., 1979).

Note that the drop in performance from the 3-step task to the 9-step task is only 18%, while the drop as steps increase from 9 to 14 is 31%; and the addition of just one step from the 14 to 15-step tasks causes another 21% drop. As the number of task steps increases, the performance decrements become more severe. This is an example of the limitation on human memory known to psychologists as "the magic number 7 plus or minus 2" (Miller, 1956); when one is asked to remember more than 9 items, the mind is likely to become a blur. This is especially true if the items must be remembered in order, the issue to which we turn next.

In some military tasks, such as "Identify Terrain Features on a Map," the steps can be performed in any sequence. Other tasks, such as "Splint a Fracture," have only one correct sequence. For a third type of task, for example, "Perform Operator Maintenance on an M16A1 Rifle," some steps must be performed in sequence and others can be performed in any order.

Psychologists have long known that memory for order information is especially slippery (Conrad, 1960; Foos & Sabol, 1981). Army research on memory for sequence has confirmed the expectation that tasks one can perform in any sequence are easiest to remember. Somewhat surprisingly, however, it turns out to be easier to remember a specific sequence for all steps than for only some of the steps (Hagman & Rose, 1983; Rose, Radtke, Shettel, & Hagman, 1985); that is, *the hardest task to remember is one that has a fixed sequence imbedded in other interchangeable steps*.

Some tasks provide feedback for some or all of the task steps, indicating when a step has been performed correctly. Examples of tasks with feedback are disassembly tasks where removing one part reveals the next part to be tackled or tasks where performing a step causes observable results, such as a panel lighting up or a warning buzzer sounding. *Feedback makes task steps less likely to be forgotten* (Hagman & Rose, 1983).

For sequential tasks, feedback may be especially beneficial when it acts as a cue for remembering the next step to be performed. In the ARI retention study of basic training tasks, the task steps that were forgotten most frequently were those that were not cued by the sequence of steps or by the equipment (Shields et al., 1979). For example, when disassembling an M16 rifle, soldiers frequently forgot the first step, the safety step of clearing the weapon.

b. Task Demands. The task components of knowledge, decision, and execution, used earlier to classify tasks in general, return here as aspects of tasks within the procedural class.

That is, procedural tasks can vary greatly in these aspects, as described below, and this variation is reflected in how well soldiers can retain memory for the tasks.

For tasks that involve recall of terms, definitions, names, locations, and other facts (see Figure 1), *memory is directly affected by the number and complexity of facts that must be remembered*. The findings for number of facts are similar to the findings for number of task steps described above (Figure 5). Tasks that do not require soldiers to recall any auxiliary facts, or only a few, are remembered best; tasks that require 4 to 8 such items are remembered well; but tasks that require recall of more than 8 pieces of information suffer rapid decay without constant practice (Rose, Radtke, et al., 1985; Semb & Ellis, 1994).

A related consideration is how hard these auxiliary facts are to remember. Some tasks require concurrent recall of only a few items, but those items, by their nature, easily slip the mind. For example, call signs and radio frequencies are notoriously forgettable, because they are assigned at random for exactly the purpose of being non-predictable. Failure to recall just one such crucial fact may make some tasks impossible.

Regarding demand for decision skills within procedural tasks, we have already seen that memory for such skills is fairly stable for periods as long as a year after learning (see Figure 2). However, decision-making or cognitive skills do suffer some decay; they are more likely to be forgotten than simple motor skills, such as saluting or marching.

Tasks with several cognitive elements, those that require multiple steps of judgment or decision-making, will suffer more degradation over time than tasks with just one or two such steps. Further, some cognitive components are more complex than others; tasks that demand processing of large amounts of technical information or rapid decision-making (e.g., setting priorities for targets) may be blocked by the break down (overload, burnout) of one complex cognitive skill (Rose, Radtke, et al., 1985).

Regarding demands for execution skills with procedural tasks, almost all procedures involve some degree of motor control of finger, hand, and arm movements. It turns out that *tasks requiring an intermediate degree of motor control are remembered best*; these are usually continuous execution tasks, such as typing or flying a helicopter. As discussed in the section on execution skills, memory for these continuous tasks remains high for long periods.

On the other hand, some discrete procedural tasks that require a high degree of motor control may also be done rarely, such as the occasional repair of delicate equipment. In such cases, unpracticed performance is likely to be poor. Whereas the well-practiced hand is steady, the anxiety caused by knowing that one's skills are dull may be enough to interfere with completing the task.

Surprisingly, however, ARI researchers (Rose, Radtke, et al., 1985) found that tasks with only a minor requirement for fine motor control, such a hammering a nail, or those that involve sheer strength, are more vulnerable to decay than are tasks that require moderate precision and accuracy. Perhaps the concentration needed for that precision aids in the formation of solid overall task memories.

c. Task Environment. The environment in which soldiers complete a task can strongly influence their performance (Lampton, Bliss, & Meert, 1992). Two possibly incompatible considerations apply. To insure that the result is a valid reflection of amount learned, testing should be conducted under the same conditions that held during training sessions. However, to insure that the result is a valid predictor of future proficiency, testing should be conducted, as far as possible, under conditions similar to those in which the soldier will be asked to perform the task on the job. The following two factors relate to the situation under which the soldier's memory for a particular task is tested.

Job aids or memory aids facilitate job performance by minimizing the need for recall, and they come in all shapes and sizes. Some memory aids are taught to soldiers in training; for example, S-A-L-U-T-E is included as a mnemonic device in the Soldier's Manual of Common Tasks. By providing retrieval cues, it helps soldiers to remember that, when completing the task, "Report Enemy Information," they should include information on the enemy's *S*ize, *A*ctivity, *L*ocation, *U*nit, *T*ime, and *E*quipment. Other job aids include technical manuals that are meant to be used on the job, instructions printed on forms detailing what information goes where, and labels with start-up instructions attached to equipment. Most maintenance tasks, for example, require use of technical manuals as job aids, and many operator tasks involve job aids in the form of checklists to ensure that the equipment is ready for operation.

But job and memory aids vary greatly in quality. A truly effective job aid allows the user to perform the entire task with no additional information or help. Such an aid, clearly written in familiar terms, is easy for the soldier to use. A poor job aid, on the other hand, requires the user to have additional expertise or information to perform the task; it only really helps someone who mostly has no need for it.

Research has consistently found low error rates when high-quality job aids are used (Hagman, 1980b; Post, 1970). An Army study of Chaparral missile system crews, for example, found no decline in performance on six tasks up to four months after initial training. As intended, soldiers performed each task with easy access to their technical manuals (Shields, Joyce, & Van Wert, 1979).

Some tasks have time limits that must be met for some or all task steps. Examples are assembling an M60 machine-gun, donning a gas mask, and performing CPR. Time limits have a direct effect on retention by defining what it means to say a soldier is proficient on a particular task. One effect of the passage of time without practice is a general slowing of both physical and mental performance; "rusty" soldiers may fail to meet a strict time limit, even when they know what needs to be done.

And it turns out that *only time limits that are difficult to meet have the effect of making a task hard to remember* (Rose, Radtke, et al., 1985). Such strict time limits add to the stress experienced by the soldier being tested on a task, and the stress may make it hard for the soldier to concentrate on important aspects of the task. In fact, time limits help mimic the situations in which some tasks must be done. Appropriately, it is mostly the set of tasks soldiers must learn to perform well under stress—those related to combat and safety—that include established time limits.

Predicting Retention from Task Factors. All of this has been taken into account in the development of an ARI research product. In 1981, under the sponsorship of the Army Training Board, ARI undertook a 3-year effort to organize and integrate many of the retention research findings just described into an instrument for predicting how rapidly individual procedural tasks are forgotten. The result of this effort is the *User's Manual for Predicting Military Task Retention* (Rose, Radtke, et al., 1985), also called the User's Decision Aid (UDA). The UDA was designed to guide the user through a process of numerically rating an individual task on the factors just discussed. Figure 6 displays a flowchart for the rating process taken from Rose, Radtke, et al. (1985).

The inputs for these factor ratings are provided when subject matter experts (SMEs) on the task answer ten questions. The output is a single score that predicts the decline in performance among soldiers who start out 100% proficient on that task. It identifies a curve that gives the percentage of soldiers in a unit who will be able to perform the task correctly after a given interval of no practice.

Training managers can use the UDA to address such issues as: How quickly will a particular task be forgotten? Among several tasks, which is most likely to be forgotten or remembered after a given interval? When should reacquisition training on a particular task be conducted to keep group performance from falling below an acceptable level?

It should be noted that the UDA process was not designed to address the difficulty of learning a task or how to conduct training. It focuses on task characteristics and does not take into account any techniques or strategies used during initial training or during the retention period to counteract forgetting. These issues will be discussed in a later section.

The Army conducted an extensive validation study of the UDA on 22 tasks for the Cannon Crewman MOS (Rose, Radtke, et al. 1985). Each task was rated by five task experts; the inter-rater reliability was high (average correlation greater than .90); that is, for a given task, there was strong agreement among the answers given by the raters to the ten UDA questions. Soldiers were trained to 100% proficiency on all tasks, and retention tests were given at intervals of 2, 5, and 7 months. The UDA scores accurately predicted retention performance (percent of soldiers performing at a "Go" level) at all three intervals, with the best accuracy (correlation greater than .90) at the 2-month interval.

The study also compared the UDA to another approach for predicting performance—directly measuring task difficulty by determining what percentage of soldiers performed at a "Go" level on their first attempt at the task immediately after training. The results showed that the UDA and this "acquisition performance" measure were about equally accurate

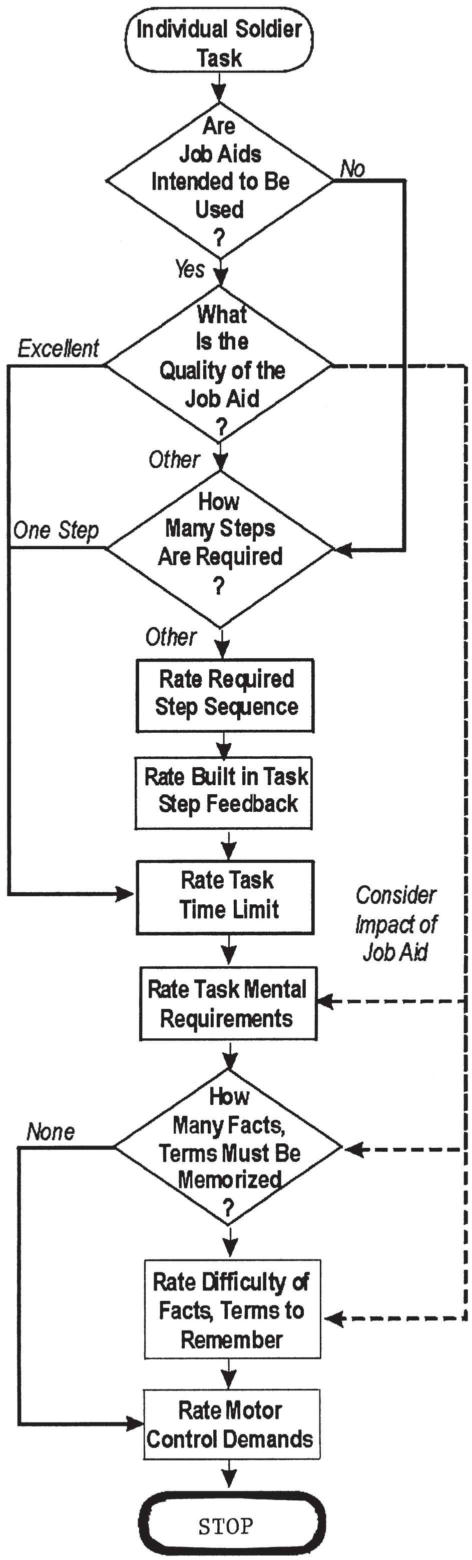

Figure 6. Flow diagram of the User's Decision Aid (from Rose, Radtke, et al., 1985).

as predictors of retention at each retention interval (all with a correlation greater than .60), with the UDA noticeably the better predictor at the shortest interval. The researchers argued that the UDA is more cost effective, since it can be applied on a few SMEs without requiring the collection of large amounts of acquisition performance data. The UDA can be applied even to proposed tasks and can provide predictions of retention even before any widespread training has been given.

Since its development, the UDA has been applied successfully to tasks in a number of military specialties, including vehicle mechanics (Macpherson, Patterson, & Mirabella, 1989), radio and communication network operators (Sabol, Chapell, & Meiers, 1990), quartermasters (Wisher et al., 1991), combat engineers and masonry/carpentry specialists (Kern, Wisher, Sabol, & Farr, 1993), field medics and air defense missile crews (Wisher, et al., 1996a), as well as to the tasks involved in peace support operations (Wisher, Sabol, & Ozkaptan, 1996).

ARI has plans to continue research using the UDA. Studies have been or soon will be conducted on the applicability of the UDA to predicting the retention of digital skills, those needed by soldiers who operate the Army's increasingly complex computer-based systems (Sanders, 1999; Sabol & Macpherson, 2000).

Individual Factors. All of the preceding has been in answer to the first question we asked in the introduction, "How fast does forgetting occur for different kinds of skills?" We have distinguished skill at cognitive and perceptual-motor tasks from skill at procedural tasks and used the UDA to answer our first question for different procedural tasks. We now address the second question, "Are some individuals more likely to forget than others?"

That is, in addition to the factors capture by the UDA, two others that affect forgetting of procedural tasks are tied to the individual soldier: a. *original learning*, mostly a matter of training time, how much opportunity the soldier has had to learn the task in the past, and b. *aptitude*, an individual difference factor, how strong an "aptitude for learning" the soldier brings to the task situation. As one might expect, these two strongly interact (Rowatt & Schlechter, 1993).

a. Original Learning. Original learning refers to the amount of knowledge and skill the trainee has acquired by the end of training but before a job assignment. In military training courses, original learning can range from just passing a course with a grade of 65 or 70 percent to continuing to practice and learn even after reaching a criterion of 100 percent (e.g., field stripping an M16A1 rifle). Practicing a task after it has been learned well enough to be performed correctly is referred to as "overlearning." The level or degree of original learning is probably the most significant single factor affecting forgetting (Fleishman & Parker, 1962; Farr, 1987); in particular, a task that is "overlearned" turns out to be highly resistant to decay (Krueger, 1929; Jones, 1989).

For example, an ARI study of electrical repairers found that increasing the number of training sessions on a complicated test station reduced both performance time and errors two weeks after training (Hagman, 1980b). Another ARI study of training to boresight and zero the main gun of the M60A1 tank compared soldiers trained to one correct performance with soldiers trained to three successive correct performances. After five weeks with no practice, the group trained to three correct performances had fewer errors (Goldberg, Drillings, & Dressel, 1981).

b. Aptitude. Aptitude for learning is usually measured by a paper-and-pencil test and is predictive of an individual's success in a school setting. In fact, educational attainment is sometimes used as a surrogate for measuring aptitude directly. In the study described above on learning via film by recruits during World War II (Hovland, et al. 1949), graduates of college, high school only, and grade school only were compared. Educational level predicted performance on the factual quiz for the control groups that did not see the film, as well as predicting the gains on the quiz for those who saw the film.

The researchers discussed their results as follows:

> [Higher aptitude soldiers,] as a function of both selection and training, probably have a *higher degree of interest* in the material presented and *more motivation* to learn it. [They]. . .have acquired a *better context of related information* which would facilitate the acquisition of new facts. . .[and] probably have learned *better techniques of learning and remembering* facts presented to them (p. 153, emphasis in the original).

Military enlisted personnel vary widely in such aptitude as measured by the Armed Services Vocational Aptitude Battery (ASVAB). Training and job assignments are based in part on ASVAB scores or, rather, on one of the composite scores obtained by adding together an individual's scores of several subtests. The composite score most useful as a general predictor of an enlistee's ability to benefit from original training is known as the Armed Forces Qualification Test (AFQT). This is a combination of subtest scores measuring verbal and numerical aptitudes.

The power of AFQT scores to predict training success (and, therefore, level of original learning) is well established, for example, by work at the Air Force's Armstrong Laboratory (Ree & Earles, 1991; Earles & Ree, 1992). Research for ARI's Army Selection and Classification Project (Project A) showed that aptitude measures also predict later job performance; while measures of vocational interest and spatial and perceptual-motor abilities were important predictors of such measures as General Soldiering Proficiency, measures of aptitude for learning were the best predictors (Campbell, 1990). However, the influence of aptitude on skill retention is not so clear.

On the one hand, several studies have shown that, although high-aptitude trainees learn more rapidly than low-aptitude trainees do, their rate of forgetting is sometimes the same (Hagman & Rose, 1983). For example, in an Army study of 13 basic training tasks (see Figure 7), high-aptitude soldiers out-performed low-aptitude soldiers both at the end of basic training and six weeks later; but the performance differences between the high and low aptitude soldiers on the six-week test were the same as at the end of basic training (Vineberg, 1975). In a similar ARI study of knowledge and skill among radio operators (Palmer & Buckalew, 1988), although ASVAB soldiers' aptitude scores explained about 25% of the variability in their performance both immediately after training and three weeks later, an individual's aptitude score did not predict how much one's performance would decay over those three weeks.

On the other hand, higher-aptitude soldiers are more likely than lower-aptitude soldiers to reach the level where overlearning—practice beyond the point of correct performance—can occur, if the same amount of training time is available to all. Since, as noted above, those who overlearn a task will show less memory decay over periods without practice, higher-

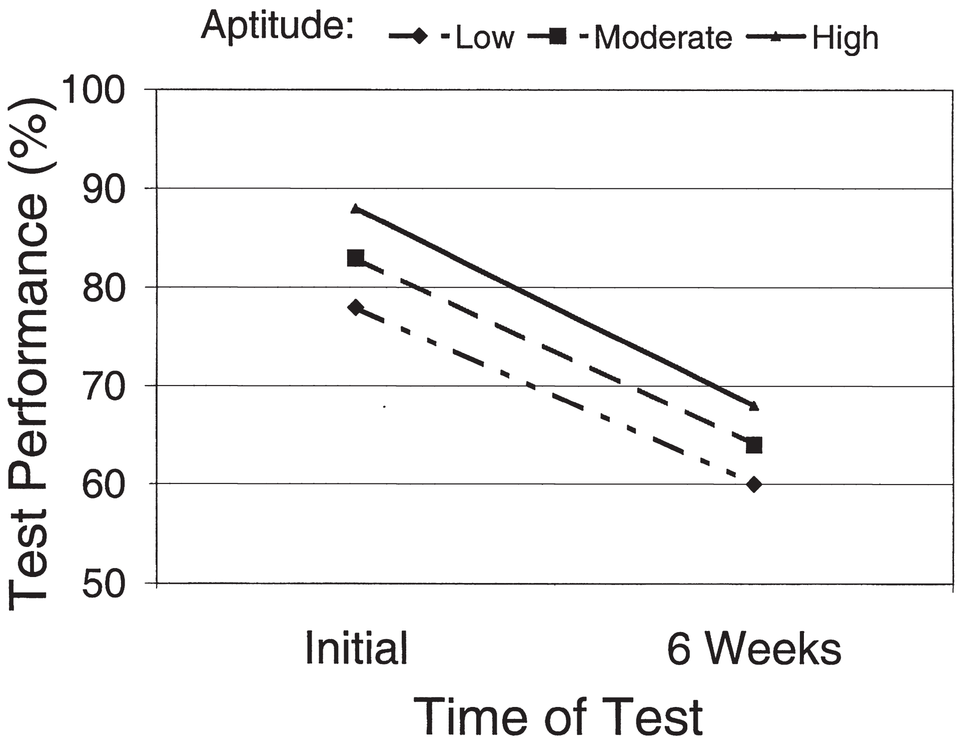

Figure 7. Soldier aptitude and memory for basic training tasks.

aptitude soldiers will show greater skill retention in these situations. To a large extent, the important aspect of the situation is the measurement of success; overlearning will occur when that measurement is such that some individuals approach or reach maximum performance early (i.e., a ceiling effect). If, however, success is measured in a way that allows continual improvement, the outcome shown in Figure 7 will apply.

The effect of high aptitude and, presumably, overlearning upon retention was shown in the already-mentioned study (Fig. 3) of IRR soldiers called to duty for Operation Desert Storm (Wisher et al. 1991). Demographic data included time out of service (TOS), that is, time since separation from active duty and return to civilian life, aptitude (most recent AFQT score), and most recent score on the (now discontinued) Skill Qualification Test (SQT), which periodically measured soldiers' MOS skills. These measures, as well as performance data, were collected for thousands of soldiers from more than 25 MOSs. Performance measures included both written job knowledge tests and hands-on performance tests.

Partial results from the multiple regression analyses are shown in Table 2. We found that, in most MOSs, the best predictor of skill retention by an individual was that soldier's SQT score, which we take as a measure of the highest level of learning the soldier had achieved as a result of original training and subsequent practice on the job. The next best predictor was AFQT score.

To elaborate, high-aptitude trainees, by definition, learn more quickly than do their lower-aptitude peers. Further, the more time soldiers of any aptitude level spend on active duty, the more opportunities they have to practice the knowledge and skills acquired in training. Therefore, both high aptitude and long active duty time are predictive of the experience of overlearning; and this experience of overlearning is predictive of resistance to forgetting.

This expectation was confirmed when both groups, soldiers with high aptitude and those with long prior active duty, did well on the measures of skill and knowledge retention, before any retraining was given. Also, as expected, in data not shown in Table 2, soldiers

Table 2. Correlation Coefficients (simple *r*) of knowledge test scores with demographic measures for several quartermaster MOSs during Operation Desert Storm.

Before Rapid Train-up:	Demographic measure			
	SQT	AFQT	TOS	R^2
MOS				
Equipment Spec.	.30	.32	−.08	20%
Accounting Spec.	.40	.39	−.35	31%
Storage Spec.	.48	.27	−.13	23%
Unit Supply Spec.	.46	.30	−.23	36%
Petroleum Spec.	.42	.31	−.01	21%
After Rapid Train-up:	**Demographic measure**			
	SQT	AFQT	TOS	R^2
MOS				
Equipment Spec.	.25	.23	−.14	11%
Accounting Spec.	.43	.53	−.30	40%
Storage Spec.	.42	.40	−.18	26%
Unit Supply Spec.	.13	.19	−.09	0%
Petroleum Spec.	.40	.30	−.05	21%

with both high aptitude and long prior service did best.

The surprising finding was that the length of time between separation from active duty and the IRR call-up (i.e., the retention interval) had little effect on forgetting. Increased length of separation was only a weak predictor of a decline in retention performance; the other predictors—lower aptitude and shorter active duty—were, for most of the MOSs studied, much stronger predictors of performance decline. The lack of a retention interval effect here is explained by assuming that most of the IRR soldiers had already suffered most of the forgetting they ever would for most of the tasks studied. That is, after months without practice, they were at the far right of the curves in Figure 4.

In a subsequent study, we looked at mobilized IRR soldiers who had once been field medics (Wisher et al., 1996b). Partial results of the multiple regression analysis are shown in Table 3. (Results for those soldiers who were mobilized from medical-related jobs in civilian life, hospital workers or emergency ambulance technicians, for example, are excluded here; all such soldiers tended to show high recall of their military medical tasks.) Once again, the length of time a soldier had been separated from active duty did not have significant predictive value (and, therefore, does not appear in Table 3), although aptitude and length of prior active duty did.

Table 3. Significant Predictors of Performance Measures During Mobilization of Field Medics

Before Rapid Train-up:
- Written Knowledge Test (Mean = 69%):
  - AFQT ($p < .001$)
  - Length of Active Duty ($p < .025$)
    - $R^2 = 18\%$
- Hands-on Performance Test (Mean = 32%):
  - AFQT ($p < .0001$)
  - Length of Active Duty ($p < .0001$)
  - Type of Civilian Job ($p < .025$)
  - Rank ($p < .03$)
    - $R^2 = 44\%$

After Rapid Train-up:
- Written Knowledge Test (Mean = 79%):
  - AFQT ($p < .001$)
    - $R^2 = 13\%$
- Hands-on Performance Test (Mean = 92%):
  - (No significant predictors)
    - $R^2 = 0\%$

However, for those medics mobilized from non-medical civilian jobs, the set of AFQT scores was a strong predictor of their knowledge of and ability to perform medic tasks, even before any retraining was given. The failure of AFQT score to predict hands-on performance after retraining is due to the lack of variability in that performance; 92% received a "Go."

The same strong predictive power of AFQT scores was reported for retention of common task performance by soldiers mobilized from the IRR (Sabol, Maisano, & Wisher, 1996). This study is discussed in some detail below, in the context of skill reacquisition; for now, the important point is that AFQT was a strong predictor of retention only for those who had previously spent a full (at least two-year) tour on active duty. While, averaged across tasks, 43% of soldiers with low (less than the mean) AFQT scores retained these tasks, 65% of soldiers with high (at or above the mean) AFQT scores retained them ($p < .05$). As in the previous results, among soldiers who were given repeated opportunity to learn and practice their tasks and then a long period without practice, the higher-aptitude soldiers could recall the tasks significantly better. This effect may be due directly to increased original learning or indirectly to better retention. Either way, it exemplifies the interplay of aptitude and opportunity to learn that yields the benefit of "overlearning."

IMPROVING PERFORMANCE

The ultimate goal of all this research is to provide Army trainers with information they can use to improve soldiers' job knowledge and skills. We are thus ready to address the third question raised in the introduction, "What instructional strategies are effective in reducing forgetting?" The following two sections provide a quick summary of recommendations to produce high retention, involving both original learning and refresher training.

Improving Skill Retention. A solidly research-based approach available to trainers and training managers for improving skill retention is to *maximize the amount of original learning* that soldiers carry with them from their initial training. This can be accomplished by increasing the number or length of training sessions or the number of practice repetitions (Trumbo, Noble, Cross, & Ulrich, 1965). We stressed above that amount of original learning or degree of overlearning that a soldier experiences during initial training is the best predictor of how good that soldier's skill retention will be.

A second means of improving retention is to *use spaced or "distributed" repetitions during practice sessions.* Substantial laboratory research (e.g., Cain & Willey, 1939) shows that inserting a time interval between repetitions of a task during learning increases retention. Army researchers have extended this finding to Army tasks. In a maintenance task study, one group of fuel and electrical repairers performed three task repetitions in succession (massed repetitions), while another group performed the same task every other day (spaced repetitions). When both groups were tested two weeks later, the massed group took 51 percent longer to complete the task and committed 40 percent more errors than the spaced group (Hagman, 1980c).

A third technique for improving retention is to *employ frequent testing during training* (Landauer & Ainslie, 1975; Foos & Fisher, 1988). In a series of studies involving motor skills, ARI researchers found that repeated testing trials resulted in superior retention (Hagman, 1980a, 1980d, 1981).

Another technique, task-oriented training, has been the subject of considerable study. This type of training involves using the context of the task to teach the factual knowledge and cognitive skills required for task performance. It is often contrasted with topic-oriented training, in which information is taught more abstractly, without reference to job applications. For example, in courses on the principles of basic electricity and electronics, the instruction may or may not refer to how and where principles such as Ohm's or Coulomb's Law will be applied when trainees begin their job assignments.

Researchers have shown that *task-oriented training is more effective at producing both high original learning* (e.g., Goffard, Heimstra, Beecroft, & Openshaw, 1960) *and good retention* (e.g. MacKenzie & White, 1982; Sturges, Ellis & Wulfeck, 1981). For example, a Navy-sponsored study compared task-oriented and topic-oriented instruction on metal fasteners (e.g., bolts, screws, nuts) in a basic mechanics course. Trainees in both the topic- and task-oriented training conditions were taught to a 90% criterion; after 6 months, the task-oriented trainees recalled significantly more than did the topic-oriented trainees.

A large number of research studies have shown that *peer tutoring, having students teach each other, enhances original learning* (e.g., Schlecter, 1988). But two studies by Navy researchers showed that peer tutoring *also improves retention.* In the first study, performance for both the peer tutors and the students who received the tutoring was near 100% at the end of initial learning. Six months later, however, the peer tutors remembered significantly more than did the students they tutored (Semb, Ellis, & Araujo, 1993). The second study examined the effects of tutoring over longer retention intervals. Tutors were found to retain more than non-tutors did for periods as long as eight years (Ellis, Semb, & Cole, 1998).

This is apparently an example of the old saying, "To teach is to learn twice." In psychological terms, anticipation of the role of tutor forces the soldiers to process the material more fully than they would otherwise have done; and a deeper level of processing is known to improve retention (Craik and Lockhart, 1972). The tutors may, for example, generate practical analogies and applications for their pupils that give the tutors themselves new insights into the principles they are teaching.

A final approach to improving retention is currently being applied in Europe. For soldiers deployed to Bosnia and Hungary, ARI developed a Trainer's Guide for Refresher Training that, on the basis of results from the UDA, ranked 27 tasks needed for this operation in terms of their vulnerability to decay (Wisher et al., 1996). For example, the tasks "Extraction from Minefield" and "React to Civilian on Battlefield" were predicted to show major problems due to decay after only two months without practice.

This information was provided so that those in charge of training for these soldiers could *create an optimal schedule for soldiers' refresher training.* With this UDA-generated guide, training planners can foresee when skills would decline below acceptable levels and move proactively to forestall that decline with a program of periodic task review. See Fisher, Wisher, and Ranney (1996) for a mathematical treatment of the issues involved in optimizing such a schedule. This kind of ongoing refresher training, distributed throughout a soldier's active duty years, has a counterpart in the concentrated "rapid train-up" portion of a mobilization, discussed below.

Improving Skill Reacquisition. Despite the best efforts of Army trainers and their use of proven techniques for optimizing retention, soldiers will still experience decay of their military knowledge and skills. Personnel called to duty from the IRR or active duty soldiers deployed overseas may lose proficiency due to a lack of practice opportunities in the months (or even years) preceding activation or deployment. The problem of retention then becomes the problem of skill reacquisition during a "rapid train-up."

ARI was asked to address this issue in 1993. In addition to assessing the extent of skill decay in both active duty and IRR soldiers, we began to develop guidelines for retraining and for predicting how rapidly skills can be reacquired.

This research program was based on the earlier work on skill retention described above, especially the results for medics mobilized to active duty from civilian jobs in the medical field (Sabol, Kern, Eidelkind, & DiMarino, 1993; Wisher, Sabol, Maisano, et al., 1996). The finding that civilian jobs strongly affected retention of military skills led us to explore strategies for reestablishing job context for IRR soldiers. We reasoned (Sabol, Maisano, & Wisher, 1996) that soldiers whose civilian jobs were similar (although not identical) to their military specialties did not need time to reinstate the "frame of mind" or job context required for their military tasks. If the job context could be reestablished for IRR soldiers by using exportable technology, such as computer-based training or videotape presentations, the time required for reacquisition training could be reduced.

To test this hypothesis, we prepared two different videotape presentations that showed two sets of three medical-related common tasks being performed in accordance with the 1994 Soldier's Manual of Common Tasks. In a study reminiscent of that on recruits during World War II described above (Hovland, et al., 1949), one video was shown to half of a sample of 100 soldiers, and the other video was shown to the remaining half. Several days later, all soldiers performed all six tasks.

The demographic findings (Sabol, 1998a) were consistent with the previous IRR studies: (1) Soldiers who had completed a full tour of active duty performed better than those who had received only a few months of MOS training (and so had little opportunity for overlearning), (2) soldiers with above-average aptitude performed better (within the full-tour group, significantly so, $p < .05$), and (3) retention interval had little effect on performance. Performance for tasks shown on the videotape was significantly better ($p < .001$) than for tasks not shown; on some tasks, performance differences were as great as 30 percent (from 60% to 90% of soldiers getting a "Go," $p < .01$).

Exposure to a simple five-minute presentation thus had a dramatic effect on task performance, apparently by reestablishing job context for the mobilized soldiers. Many of the soldiers reported that the videotapes were "very useful," in that they "brought back a lot" of task knowledge. On the basis of these results, we proposed that videotape and similar technologies (e.g., internet-based training) could be employed in future mobilizations to shorten the time required for reacquisition (Sabol, 1998b). These technologies and their application are in rapid development; see Wisher and Champagne (2000) for a review of successful applications of distance learning techniques for training and retraining in the military.

Predicting Reacquisition Time. Finally, in addition to assessing skill decay and exploring retraining strategies, we combined data from several of our studies, in order to document, at least roughly, how much time mobilized soldiers need to reacquire skills. This represents a preliminary attempt to answer the question: "How difficult will it be for soldiers to reacquire skills they have forgotten?"

The Reacquisition Curve in Figure 8 displays data from three of our studies of IRR soldiers called back to active military duty from civilian life as part of a mobilization exercise. Two data points are shown from each of these three studies, one point for retention and one for retraining. That is, each study contributed, for its set of procedural tasks, the performance of soldiers after zero retraining (the retention measure) and their performance after the specific amount of retraining time (averaged across tasks) used in that particular mobilization. A final point is added to the figure to represent the obvious expectation that if soldiers were provided with retraining that lasted as long as their original training, all would become proficient.

The performance measure in Figure 8 is the percentage of soldiers who performed the tasks successfully. The time available for retraining is expressed as a percentage of the original amount of time required in the Army school to train each task, according to the official Program of Instruction (POI). For each study, this value was averaged across all tasks. Note that this POI time is an alternative method of gathering a set of data similar to the "acquisition performance" investigated by the developers of the UDA and found to be a good predictor of retention. Both provide a general measure of

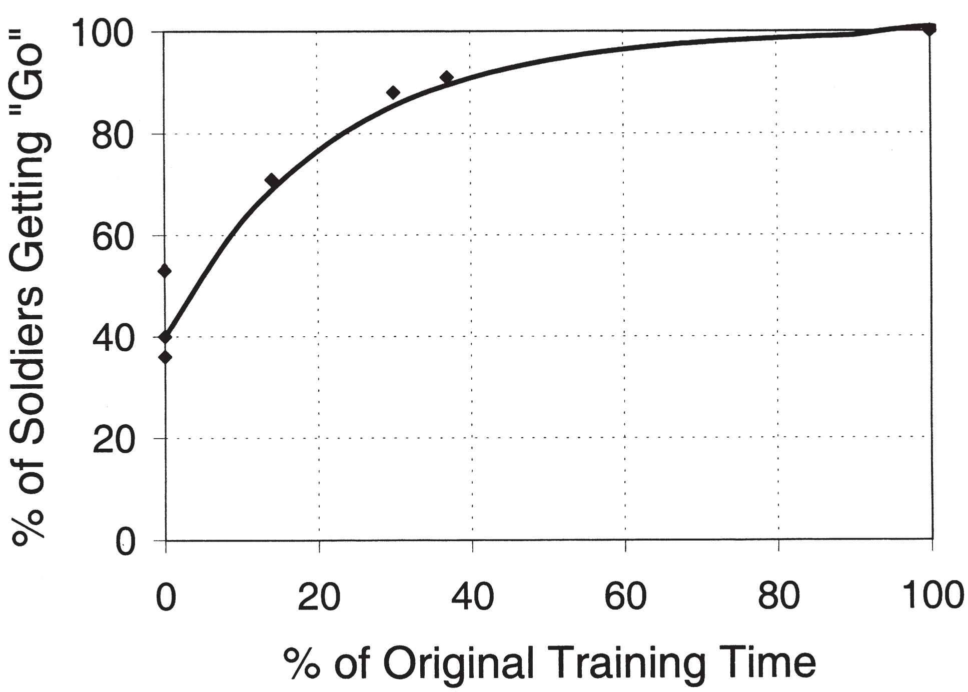

Figure 8. The Reacquisition Curve: Performance as a function of time spent retraining.

how difficult tasks are to train, although in this case the measure is averaged over the dozen or so tasks included in each rapid train-up.

The fact that a smooth curve was obtained when data from several different studies were combined in this way supports the idea that a general relationship is being revealed. That is, we consider Figure 8 to be a first approximation of the relationship between how long it takes to train a task originally and how much time is needed to retrain soldiers to the point where any desired percentage of soldiers will be again "up to speed" on the task. It is assumed to apply to any situation (combinations of tasks and retention intervals) that would yield the same retention performance as found in these studies, an average 40% of the soldiers remembering enough to receive a "Go."

The figure can be used by trainers to plan how much retraining time is needed in such situations to reach a preset level of proficiency, such as 90%. It suggests, for example, that 35% of original training time is needed to retrain soldiers at around 40% proficiency to the point where 90% of them will perform at a "Go" level.

Application would be as follows: If it has been determined, by long experience, that 100 hours of school time is needed to successfully train a particular task, then about 35 hours (35% × 100 hours original training time) should be devoted to retraining soldiers, 100% of whom once knew the task but 60% of whom have now forgotten it. These 35 hours of retraining would bring another 50% of the soldiers back to proficiency (adding to the original 40% for a total of 90%). According to Figure 8, providing more than 35 hours of retraining would not produce much addition benefit. This figure, then, gives a rough recommendation for how much retraining should be scheduled for this task. More research is needed to describe the similar curves that should apply when tasks have undergone different degrees of skill decay.

SUMMARY

In the post-Cold War world, the option to rapidly mobilize and deploy highly skilled personnel is essential. But the success of this option for the Army depends upon soldiers' retention of the military knowledge and skills they once learned or on their capacity for rapid re-learning (Binkin & Kaufman, 1989).

ARI has been studying the retention of knowledge and skills for more than three decades. This work has resulted in a detailed understanding of the patterns of forgetting that occur in job knowledge and in cognitive and perceptual-motor skills. For procedural skills, ARI has identified the factors that affect forgetting and developed the *User's Manual for Predicting Military Task Retention*. With this manual, Army trainers and planners can predict how rapidly individual procedural tasks will be forgotten; this information enables them to optimize the scheduling of refresher training.

Researchers have also identified instructional strategies that Army trainers can use to improve soldiers' retention of what they were originally taught and speed their relearning of skills grown dull. Army planners can now identify those individuals least likely to suffer major skill decay while in the IRR. They can even make rough predictions of the time needed to reacquire proficiency on different tasks. All these are potential improvements in the retraining portion of any future mobilization.

Acknowledgment

The authors would like to thank Dr. John Ellis for technical assistance and Ms. Jennifer Pawluk for editorial assistance.

REFERENCES

Adams, J. (1987). Historical Review and Appraisal of Research on the Learning, Retention, and Transfer of Human Motor Skills. *Psychological Bulletin*, Vol 101, No 1, 41–74.

Allen, G., Secundo, M., Salas, E., and Morgan, B., Jr. (1983). *Evaluation of Rate Parameters of the Acquisition, Decay, and Reacquisition of Complex Cognitive Skills* (Technical Report ITR-82-27). Norfolk, Virginia: Old Dominion University, Center for Applied Psychological Studies.

Ammons, R., Farr, R., Bloch, E., Neumann, E., Day, M., Marion, R., and Ammons, C. (1958). Long-term Retention of Perceptual Motor Skills. *Journal of Experimental Psychology*, Vol 55, 318–328.

Anderson, J., Fincham, J., and Douglass, S. (1999). Practice and Retention: A Unifying Analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Vol 25, No 5, 1120–1136.

Arthur, W., Bennett, W., Stanush, P., and McNelly, T. (1998). Factors that Influence Skill Decay and Retention: A Quantitative Review and Analysis. *Human Performance*, Vol 11, No 1, 57–101.

Austin, S., and Gilbert, K. (1973). Student Performance in a Keller-Plan Course in Introductory Electricity and Magnetism. *American Journal of Physics*, Vol 41, 82–87.

Bahrick, H. (1984). Semantic Memory Content in Permastore: Fifty Years of Memory for Spanish Learned in School. *Journal of Experimental Psychology: General*, Vol 113, 1–29.

Bahrick, H., and Hall, L. (1991). Lifetime Maintenance of High School Mathematics Content. *Journal of Experimental Psychology: General*, Vol 120, 20–33.

Bahrick, H., Bahrick, P., and Wittlinger, R. (1975). Fifty Years of Memory for Names and Faces: A Cross-Sectional Approach. *Journal of Experimental Psychology: General*, Vol 104, 54–75.

Binkin, M., and Kaufman, W. (1989). *U.S. Army Guard and Reserve: Rhetoric, Realities, Risks.* (Studies in Defense Policy). Washington, D.C.: The Brookings Institution.

Cain, L., and Willey, R. (1939). The Effect of Spaced Learning on the Curve of Retention. *Journal of Experimental Psychology*, Vol 25, 209–214.

Campbell, J. (1990). An Overview of the Army Selection and Classification Project (Project A). *Personnel Psychology*, Vol 43, No 2, 231–239.

Cohen, G., Stanhope, N., and Conway, M. (1992). How Long Does Education Last? Very Long Term Retention of Cognitive Psychology. *The Psychologist*, Vol 5, 57–60.

Conrad, R. (1960). Serial Order Intrusions in Immediate Memory. *British Journal of Psychology*, Vol 51, 45–48.

Conway, M., Cohen, G., and Stanhope, N. (1991). On the Very Long-Term Retention of Knowledge Acquired Through Formal Education: Twelve Years of Cognitive Psychology. *Journal of Experimental Psychology: General*, Vol 120, 395–409.

Cooke, N., Durso, F., and Schvaneveldt, R. (1994). Retention of Skilled Search after Nine Years. *Human Factors*, Vol 36, No 4, 597–605.

Craik, F., and Lockhart, R. (1972). Levels of processing: A Framework for Memory Research. *Journal of Verbal Learning and Verbal Behavior*, Vol 11, 671–684.

Cross, K., and Szabo, S. (1986). *Human Factors Research in Aircrew Performance and Training: Final Summary Report* (Research Note 86-94). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Davis, M. (1991). *Determination of Skill Degradation Rates and Retraining Requirements by AFSC: Phase II.* Alexandria, Virginia: Human Resources Research Organization.

Earles, J., and Ree, M. (1992). The Predictive Validity of the ASVAB for Training Grades. *Educational and Psychological Measurement*, Vol 52, No 3, 721–725.

Ebbinghaus, H. (1913). *Memory*. (H. Ruyer and C. Bussenius, Trans.). New York, New York: Teachers College, Columbia University. (Original work published 1885.)

Ellis, J. (1980). *Long-term Retention of Factual Information* (Technical Note NPRDC TN-80-5). San Diego, California: Navy Personnel Research and Development Center.

Ellis, J., Semb, G., and Cole, B. (1998). Very Long Term Memory for Information Taught in School. *Journal of Contemporary Educational Psychology*, Vol 23, 419–433.

Farr, M. (1987). *The Long-Term Retention of Knowledge and Skills: A Cognitive and Instructional Perspective*. New York, New York: Springer-Verlag.

Fisher, D., Wisher, R., and Ranney, T. (1996). Optimal Static and Dynamic Training Schedules: State Models of Skill

Acquisition. *Journal of Mathematical Psychology*, Vol 40, No 1, 30–47.

Fleishman, E., and Parker, J., Jr. (1962). Factors in the Retention and Relearning of Perceptual Motor Skill. *Journal of Experimental Psychology*, Vol 64, 205–226.

Foos, P., and Sabol, M. (1981). The Role of Memory in the Construction of Linear Orderings. *Memory and Cognition*, Vol 9, No 4, 371–377.

Foos, P., and Fisher, R. (1988). Using Tests as Learning Opportunities. *Journal of Educational Psychology*, Vol 80, No 2, 179–183.

Gabrieli, J. (1998). Cognitive Neuroscience of Human Memory. *Annual Review of Psychology*, Vol 49, 87–115.

Goffard, S., Heimstra, N., Beecroft, R., and Openshaw, J. (1960). *Basic Electronics for Minimally Qualified Men: An Experimental Evaluation of a Job Oriented Skills Course: Supplyman MOS 76Y10*. Alexandria, Virginia: Human Resources Research Organization.

Goldberg, S., Drillings, M., and Dressel, J. (1981). *Mastery Training: Effects on Skill Retention* (Technical Report 513). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. (1980a). *Effects of Presentation and Test Trial Training on Motor Acquisition and Retention* (Technical Rep. 431). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. (1980b). *Effects of Training Task Repetition on Retention and Transfer of Maintenance Skill* (Research Report 1271). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. (1980c). *Effects of Training Schedule and Equipment Variety on Retention and Transfer of Maintenance Skills* (Research Report 1309). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. (1980d). *Effects of Presentation and Test Trial Training on Acquisition and Retention of Movement End-Location* (Technical Report 492). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J. (1981). *Testing During Training: Why Does It Enhance Long-Term Motor Task Retention*? (Technical Report 535). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hagman, J., and Rose, A. (1983). Retention of Military Tasks: A Review. *Human Factors*, Vol 25, 199–213.

Hamilton, D. (1991, November). *Training Effectiveness of the AH-64A Combat Mission Simulator for Sustaining Gunnery Skills* (Research Report 1604). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Healy, A., and Bourne, L., Jr. (1995). *Learning and Memory of Knowledge and Skills: Durability and Specificity*. Thousands Oaks, CA: Sage.

Healy, A., Ericsson, K., and Bourne, L., Jr. (1987). *Optimizing the Long-Term Retention of Skills: Structural and Analytic Approaches to Skill Maintenance* (Research Note 87-53). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hovland, C., Lumsdaine, A., and Sheffield, F. (1949). *Experiments on Mass Communication*. Princeton, New Jersey: Princeton University Press.

Jones, M. (1989). Individual Differences in Skill Retention. *American Journal of Psychology*, Vol 102, No 2, 183–196.

Kern, R., Wisher, R., Sabol, M., and Farr, B. (1993). *Reacquisition of Skill by Combat Engineers Mobilized from the Individual Ready Reserve* (Research Report 1667). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Knerr, C., Harris, J., O'Brien, B., Sticha, P., and Goldberg, S. (1984). *Armor Procedural Skills: Learning and Retention* (Technical Report 621, ADA1532274XSP). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Konoske, P. and Ellis, J. (1986, December). *Cognitive Factors in Learning and Retention of Procedural Tasks* (Technical Report 87-14). San Diego, California: Navy Personnel Research and Development Center.

Krueger, W. (1929). The Effects of Overlearning on Retention. *Journal of Experimental Psychology*, Vol 12, 71–78.

Lampton, D., Bliss, J., and Meert, M. (1992, April). *The Effects of Differences Between Practice and Test Criteria on Transfer and Retention of Simulated Tank Gunnery Task* (Technical Report 949). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Landauer, T., and Ainslie, K. (1975). Exams and Use as Preservatives of Course-Acquired Knowledge. *Journal of Educational Research*, Vol 69, 99–104.

Lewis, D. and Lowe, W. (1956). Retention of Skill on the SAM Complex Coordinator. *Proceedings of the Iowa Academy of Science*, Vol 63, 591–599.

MacKenzie, A., and White, R. (1982). Fieldwork in Geography and Long-Term Memory. *American Educational Research Journal*, Vol 19, 623–632.

Macpherson, D., Patterson, C., and Mirabella, A. (1989). *Application of ARI Skill Retention Model to Wheel Vehicle Maintenance Tasks* (Research Report 1538). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

McKenna, S., and Glendon, A. (1985). Occupational First Aid Training: Decay in Cardiopulmonary Resuscitation (CPR) Skill. *Journal of Occupational Psychology*, Vol 58, 109–117.

Miller, G. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information. *Psychological Review*, Vol 63, 81–97.

Palmer, R., and Buckalew, L. (1988, November). *SINCGARS Operator Performance Decay* (Research Report 1501). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Post, T. (1970). *Advanced Manpower Concepts for Sea-Based Aviation Systems.* Arlington, Virginia: Serendipity, Inc.

Prophet, W. (1976, October). *Long-term Retention of Flying Skills: A Review of the Literature* (Final Report FR-ED(P) 76-35). Alexandria, Virginia: Human Resources Research Organization.

Ree, M., and Earles, J. (1991). Predicting Training Success: Not Much More than *g*. *Personnel Psychology*, Vol 44, No 2, 321–332.

Roehrig, W. (1964). Psychomotor Task with Perfect Recall after Fifty Weeks of No Practice. *Perceptual and Motor Skills*, Vol 19, 547–550.

Rose, A., Czarnolewski, M., Gragg, F., Austin, S., and Ford, P. (1985). *Acquisition and Retention of Soldiering Skills* (Final Report 671). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Rose, A., Radtke, P., Shettel, H., and Hagman, J. (1985). *User's Manual for Predicting Military Task Retention* (Research Product 85-26). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Rowatt, W., and Schlechter, T. (1993, February). *A Review and Annotated Bibliography of Literature Relevant to Armor Skill Retention* (Research Product 93-03). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Sabol, M. (1998a, February). PREMO: Accelerating Mobilized Soldiers' Reacquisition of Skills. In *1997 In-house Researchers' Colloquium* (Special Report 35). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Sabol, M. (1998b). Accelerating Mobilized Soldiers' Reacquisition of Skills. *Proceedings of the 21st Army Science Conference*, Norfolk, Virginia.

Sabol, M., Chapell, L., and Meiers, C. (1990). *Predicted Decay of Mobile Subscriber Equipment Operator Skills* (Research Product 90-11). Alexandria, Virginia: U.S. Army

Research Institute for the Behavioral and Social Sciences.

Sabol, M., Kern, R., Eidelkind, M., and DiMarino, C. (1993, November). Effects of Rapid Training on Soldiers' Occupational Knowledge. *Proceedings of the 35th Annual Conference of the Military Testing Association*, Williamsburg, Virginia.

Sabol, M., and Macpherson, D. (2000, June). *Adapting the Skill Retention Model to Digital Tasks*. Paper presented at the 68th Military Operations Research Society Symposium, Colorado Springs, Colorado.

Sabol, M., Maisano, R., and Wisher, R. (1996, August). *Predictors of Retention and Reacquisition of Military Job Knowledge*. Paper presented at the annual meeting of the American Psychological Association, Toronto, Ontario.

Sanders, W. (1999, August). *Digital Procedural Skill Retention for Selected M1A2 Tank Inter-Vehicular Information System (IVIS) Tasks.* (Technical Report 1096). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Schendel, J., and Hagman, J. (1980). *On Sustaining Procedural Skills over Prolonged Retention Intervals* (Technical Report 1234). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Schlechter, T. (1988, September). *The Effect of Small Group and Individual Computer-Based Instruction on Retention and on Training Lower Ability Soldiers* (Research Report 1497). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Semb, G., and Ellis, J. (1994). Knowledge Taught in School: What is Remembered? *Review of Educational Research*, Vol 64, No 3, 253–286.

Semb, G., Ellis, J., and Araujo, J. (1993). Long Term Retention of Knowledge Learned in School. *Journal of Educational Psychology*, Vol 85, 305–316.

Shields, J., Goldberg, G., and Dressel, J. (1979). *Retention of Basic Soldiering Skills* (Research Report 1225). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Shields, J., Joyce, R., and Van Wert, J. (1979). *Chaparral Skill Retention* (Research Report 1205, ADA069945). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Singley, M., and Anderson, J. (1989). *The Transfer of Cognitive Skill*. Cambridge, Massachusetts: Harvard University Press.

Skelton, M., and McSwain, N. (1977). A Study of Cognitive and Technical Skill Deterioration among Trained Paramedics. *Journal of the American College of Emergency Physicians*, Vol 6, 436–438.

Stanhope, N., Cohen, G., and Conway, M. (1993). Very Long-Term Retention of a Novel. *Applied Cognitive Psychology*, Vol 7, 239–256.

Sturges, P., Ellis, J., and Wulfeck, W. (1981). *Effects of Performance-Oriented Text upon Long Term Retention of Factual Material* (Technical Report NPRDC TR 81-22). San Diego, California: Navy Personnel Research and Development Center.

Thompson, T., Morey, J., and Smith, S. (1981, October). *Basic Rifle Marksmanship Skill Retention: Implications for Retention Research* (Research Report 1326). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Trumbo, D., Noble, M., Cross, K., and Ulrich, L. (1965). Task Predictability in the Organization, Acquisition, and Retention of Tracking Skills. *Journal of Experimental Psychology*, Vol 70, 252–263.

Vineberg, R. (1975). *A Study of the Retention of Skills and Knowledge Acquired in Basic Training* (Technical Report 75-10). Alexandria, Virginia: Human Resources Research Organization.

Wetzel, S., Konoske, P., and Montague, W. (1983). *Estimating Skill Degradation for Aviation Antisubmarine Warfare Operators (Aws): Loss of Skill and Knowledge Following Training* (Technical Report NPRDC TR 83-31). San Diego, California: Navy Personnel Research and Development Center.

Wick, D., Millard, S., and Cross, K. (1986, January). *Evaluation of a Revised Individual Ready Reserve (IRR) Aviator Training Program: Final Report* (Technical Report 697). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Wisher, R. (1991). Desert Storm Mobilization: Skill Decay and Attitudes in the IRR (*ARI Newsletter*, Vol 7, 1–4). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Wisher, R., and Champagne, M. (2000). Distance Learning and Training, in S. Tobias and D. Fletcher (Eds.), *Training and Retraining*, New York, New York: Macmillan Reference USA.

Wisher, R., Sabol, M., Maisano, R. Knott, B. Curnow, C., and Ellis, J. (1996). *Retraining Medics for Mobilization*. Paper presented to the American Educational Research Association, San Diego, California.

Wisher, R., Sabol, M., and Ozkaptan, H. (1996). *Retention of "Peace Support Operations" Tasks During Bosnia Deployment: A Basis for Refresher Training* (Special Report). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.

Wisher, R., Sabol, M., Sukenik, H., and Kern, R. (1991). *Individual Ready Reserve (IRR) Call-Up: Skill Decay* (Research Report 1595). Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences.